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(54) Title: METHOD FOR CONTROLLING MACHINE PISTON MOVEMENT, IMPLEMENTING DEVICE AND BALANCING OF SAID DEVICE

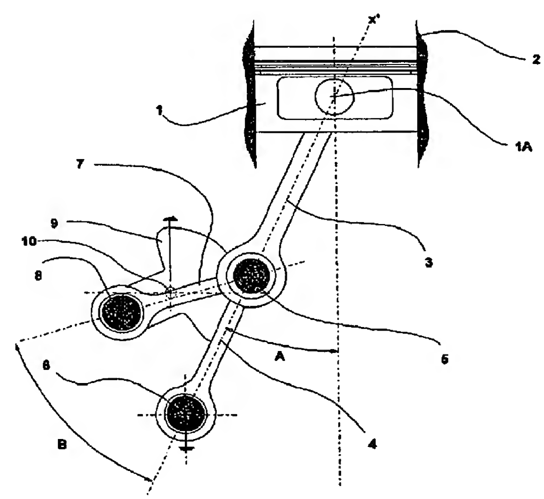
(54) Titre: PROCEDE DE CONTROLE DU MOUVEMENT DE PISTON DE MACHINE, DISPOSITIF DE MISE EN OEUVRE ET EQUILIBRAGE DU DISPOSITIF

(57) Abstract

The invention concerns a method for controlling a machine piston movement for carrying out operations such as gas transfer in engines with independent combustion chamber or such as ignition and combustion in standard engines, at a constant volume by stopping the piston and maintaining it in its upper dead centre position for a time interval. The invention also concerns an implementing device wherein the piston (1) is controlled by a pressure lever (3, 4) which is itself controlled by a crankshaft (9) and a connecting rod (7).

(57) Abrégé

Procédé de contrôle du mouvement de piston de machine permettant d'effectuer des opérations telles que transfert de gaz dans les moteurs à chambre de combustion indépendante ou telles que allumage et combustion dans les moteurs classiques, à volume constant en arrêtant le piston et en le maintenant à sa position de point mort haut durant une période de temps et dispositif de mise en oeuvre dans lequel le piston (1) est commandé par un levier à pression (3, 4) lui même commandé par un vilebrequin (9) et une bielle (7).



METHOD FOR CONTROLLING MACHINE PISTON MOVEMENT, IMPLEMENTING DEVICE AND BALANCING OF SAID DEVICE

The invention relates to the operating dynamics of the connecting rod/crankshaft system of piston engines, reciprocating compressors or any machine with a piston, and more specifically non-polluting or pollution reducing engines with an independent combustion and/or expansion chamber.

Two-stroke or four-stroke internal combustion engines operate, in the main, using a well-known connecting rod/crank system driving (and driven by) a piston sliding in a cylinder. The piston, in its downstroke, takes in an air/fuel mixture then compresses it in its upstroke toward the combustion chamber in the top part of the cylinder, at its smallest volume, where it is ignited, and its temperature and pressure rise. The gases, having thus been raised to a very high pressure, on expanding as their pressure decreases drive back the piston which, via the connecting rod, drives the rotation of the crankshaft thus creating work known as the power stroke.

The path of the piston, which describes an essentially sinusoidal curve, creates constant piston motion and, although its movement is slowed down near top dead center, the piston is always in motion. This state of affairs faces engine manufacturers with one of their greatest problems, more specifically at the time of combustion which has to be triggered by ignition prior to top dead center. The start of combustion therefore causes an increase in pressure which generates negative work which causes some of the engine output to be lost while the piston begins its downstroke, increasing the volume of the chamber tending to reduce the pressure that combustion tends to increase when the charge has not completed its combustion. Likewise, upon closure of the exhaust and

opening of the inlet, there is negative work through the drop in pressure during the movements of early opening and closure of the ports.

In his published patent application WO 96/27737, the author has described a method for depolluting an engine with an independent external combustion chamber, operating on the dual-mode principle using two sources of energy, using either a conventional fuel of the gasoline or diesel oil type, on roads (single-mode air/fuel operation) or, at low speed, particularly in towns and suburbs, adding compressed air (or any other non-polluting gas) to the exclusion of any other fuel (single-mode air operation, that is to say with the addition of compressed air). In his patent application 96/07714, the author has described the installation of this type of engine in single-mode operation, with the addition of compressed air, in service vehicles, for example town buses.

In this type of engine, in air/fuel mode, the air/fuel mixture is drawn into and compressed in an independent intake and compression chamber. This mixture is then transferred, still under pressure, to an independent and constant-volume combustion chamber where it is ignited so as to increase the temperature and pressure of said mixture. After a transfer port connecting said combustion or expansion chamber to a pressure-reducing expansion and exhaust chamber, this mixture will be expanded in the latter chamber to produce work. The expanded gases are then discharged to the atmosphere through an exhaust pipe.

When operating on air, at low power, the fuel injector is no longer operated; in this case, there is introduced into the combustion chamber, somewhat after the fuel-free compressed air from the intake and compression chamber has been let into the latter, a small amount of additional compressed air from an external reservoir where the air is stored at high pressure, for example 200 bar, at ambient temperature.

This small amount of compressed air at ambient temperature will heat up upon contact with the mass of air at high temperature contained in the combustion or expansion chamber, will expand and increase the pressure in the chamber to allow engine work to be delivered during expansion.

In this type of engine, known as a non-polluting or depolluting engine, the transfer of gases or air from the combustion chamber to the pressure-reducing expansion chamber must also begin before top dead center and create negative work which is prejudicial to the correct operation of the engine just as the pressure has to be built up in the pressure-reducing expansion chamber before the piston begins its downstroke.

One of the main problems of the conventional connecting rod/crank system is a loss of output and pollution during the operations of ignition, combustion, injection, transfer, end of exhaust and/or start of intake. To solve this problem, it has been noted that these operations take place in volumes which always vary, and specifically the piston is always in motion and the volumes generated thereby are never constant.

More specifically, the subject of the invention is a method for controlling the movement of a piston of a machine such as an engine or compressor, characterized by the means implemented and more specifically by the fact that at top dead center the motion of the piston is halted and the piston is kept at top dead center for a period of time that allows the following operations to be performed at constant volume:

- the operations of ignition and of combustion, in the case of conventional engines,

- the operations of injecting fuel, in the case of diesel engines,

- the operations of transferring gas and/or compressed air, in the case of engines with an independent combustion and/or expansion chamber,

- the operations of end of exhaust, start of admission in all cases of engines and other compressors.

It is therefore possible, in the case of a conventional 2-stroke or 4-stroke engine, to ignite the charge while the piston is kept at top dead center and while the combustion chamber remains at its smallest volume, constantly, to wait for the charge to have been completely burnt before beginning the piston downstroke, this having the effect of eliminating the back pressure during early ignition (as in current engines) and, by virtue of more complete combustion, to obtain exhaust gas emissions which cause little pollution.

In the case of a diesel engine, it is thus possible to inject the fuel while the piston is at top dead center, thus avoiding back pressures due to the start of combustion before top dead center and which produce negative work.

It is thus possible, in the case of an engine with an independent combustion and/or expansion chamber, to transfer the pressure of the gases and/or of the compressed air into the pressure-reducing expansion chamber without creating any back pressure before the piston reaches top dead center and wait for transfer to have occurred before the piston begins its downstroke increasing the volume of the pressure-reducing expansion chamber, which would have the effect of losing pressure and therefore power.

In all cases, it is possible to close the exhaust port as the piston reaches top dead center, or shortly before, thus avoiding pressure drops due to early closure and to open the inlet before the piston begins its downstroke.

Stopping the piston and keeping it at top dead center can be achieved by any means known to the person skilled in the art, for example cams, pinions, etc.

As a preference, to allow the piston to be stopped at top dead center, and according to another aspect of the invention, the piston is controlled by a pressure lever device itself controlled by a connecting rod/crank system. The term "pressure lever" is used to describe a system of two articulated arms, one of which has a stationary end or pivot and the other of which can move along an axis. If a force approximately perpendicular to the axis of the two arms is exerted when the arms are aligned on the articulation between these two arms, then the free end is made to move. This free end may be connected to the piston and control its movements. The piston reaches its top dead center roughly when the two articulated rods are one in the continuation of the other (at around 180°).

The crankshaft is connected by a control connecting rod to the articulation pin of the two arms. The position of the various elements in space and their dimensions allow the characteristics of the dynamics of the assembly to be altered. The position of the stationary end determines an angle between the axis of displacement of the piston and the axis of the two arms when they are aligned. The position of the crankshaft determines an angle between the control connecting rod and the axis of the two arms when they are aligned. The variation of the values of these angles, and of the lengths of the connecting rods and arms, makes it possible to determine the angle of rotation of the crankshaft for which the piston is halted at top dead center. This corresponds to the length of time for which the piston is stationary.

According to a particular embodiment, the entire device (piston and pressure lever) is balanced by extending the lower arm beyond its stationary end or pivot, using a mirror-image pressure lever which is

opposed in terms of direction, symmetric and of the same moment of inertia to which there is connected, with the ability to move along an axis parallel to the axis of displacement of the piston, a mass with identical moment of inertia opposed in terms of direction to that of the piston. The moment of inertia is defined as the product of the mass times the distance from its center of gravity to the point of reference. In the case of a multi-cylinder engine, the opposed mass may be a piston which is operating normally like the piston it is balancing.

The invention applies to all conventional combustion engines of all types, more particularly to non-polluting and depolluting engines with a constant-volume independent combustion or expansion chamber, just as it applies to compressors or other machines which involve pistons. The number of piston [sic], the shapes and sizes of the connecting rods may vary without in any way altering the invention which has just been described.

Other objects, advantages and features of the invention will become apparent upon reading the description, without implied limitation, of a number of embodiments which is given with reference to the appended drawings, in which:

Figure 1 depicts, diagrammatically, viewed in cross section, one example of the dynamics for controlling a piston according to the invention.

Figure 2 depicts a curve of the travel of the piston according to the invention compared with the curve of the travel of a conventional piston.

Figure 3 depicts a device according to the invention equipped with balancing using a mass of the same moment of inertia.

Figure 4 depicts a device according to the invention equipped with balancing using a piston operating in opposition.

Figure 1 shows diagrammatically, viewed in cross section, a device according to the invention and for its implementation in which the piston 1 (depicted at top dead center), sliding in a cylinder 2, is controlled by a pressure lever. The piston 1 is connected by its pin to the free end 1A of a pressure lever consisting of an arm 3 articulated to a pin 5 common to another arm 4 fixed to pivot, on a stationary pin 6. Attached to the pin 5 common to the two arms 3 and 4 is a control connecting rod 7 connected to the wrist pin 8 of a crankshaft 9 rotating about its pin 10. As the crankshaft rotates, the control connecting rod 7 exerts force on the common pin 5 of the two arms 3 and 4 of the pressure lever, thus allowing the piston 1 to move along the axis of the cylinder 2, and in return transmits to the crankshaft 9 the forces exerted on the piston 1 during the power stroke, thus causing it to rotate. The stationary pin 6 is positioned laterally with respect to the axis of displacement of the piston 1 and determines an angle A between the axis of displacement of the piston and the axis of alignment X'X of the two arms 3 and 4 when they are aligned. The crankshaft is positioned laterally with respect to the axis of the cylinder and/or of the pressure lever and its position determines an angle B between the control connecting rod 7 and the axis of alignment X'X of the two arms 3 and 4 when they are aligned. By varying the angles A and B and the lengths of the various connecting rods and arms, the dynamic characteristics of the assembly are altered to obtain a curve of the travel of the piston 1 which is asymmetric and determine the angle of rotation of the crankshaft for which the piston is kept stationary at top dead center.

By way of nonlimiting example of one embodiment of the device according to the invention, the displacement of the piston describes the curve depicted in Figure 2 with the following dimensions and positions:

crankshaft throw:	32.8 mm
length of control connecting rod 7:	99.76 mm
length of piston arm 3:	124 mm
length of lower arm 4:	128 mm

Angle A: 21.4°
Angle B: 29.6°

It can thus be seen from Figure 2 that, in this configuration, on the curve 11, the piston remains at top dead center over an angle of 70° while a curve of the displacement of a piston with a conventional connecting rod/crank system 12 with the same stroke shows that the piston stops only at a point (top dead center).

The person skilled in the art will thus be able to choose the time for which the piston is stationary at top dead center to suit the desired operating parameters: combustion period, duration of the transfer, etc. without thereby altering the principle of the invention.

This dynamic assembly is balanced according to the invention, Figure 3, by extending the lower arm 4 beyond its stationary end or pivot 6 by a mirror-image pressure lever consisting of 2 arms 4A and 3A articulated to a common pin 5A to which is attached, at the free end 1B a mass 15 moving along an axis parallel to the axis of displacement of the piston 1. The arm 4a which is the extension of the lower arm 4 is in fact the same part. With respect to the pivot point 6, the moment of inertia of the arms 4 and 4A are identical, and the same is true of the moments of inertia of the arms 3 and 3A and the moments of inertia of the piston 1 and of its balancing mass 15. The pressure lever system is thus perfectly balanced, while the control connecting rod 7 and crankshaft assembly are balanced in the conventional way. This arrangement is more particularly beneficial when balancing single-cylinder engines or non-symmetric multi-cylinder assemblies.

In the case of a symmetric multi-cylinder assembly, depicted in Figure 4, the balancing mass is an opposed piston 1C moving along an axis parallel to the piston 1, and the pistons balance each other. The arms 3A and 4A are symmetric with the arms 3 and 4 and balance each other.

The invention is not restricted to the embodiments described and depicted. The angles A and B may be positive or negative together or separately or not simultaneously zero. The number of cylinders can vary in even or odd number, the method of halting the piston and keeping it stationary at top dead center may be achieved by other means such as cams or pinions or some other way, without thereby altering the invention which has just been described.

CLAIMS

1. A method for controlling the movement of a piston sliding between a top dead center position and a bottom dead center position in a cylinder of a reciprocating engine that has a combustion and/or expansion chamber separate from but in fluid connection with the cylinder, the method being characterized in that it includes the step of substantially halting the movement of the piston at top dead center while pressure in said chamber equilibrates with the pressure in the cylinder after ignition or after the introduction of fluid into said chamber.

2. A method according to Claim 1 for controlling the movement of a piston in an internal combustion engine, characterized in that the operations of ignition and combustion are performed while substantially halting the piston at top dead center to avoid back pressures formerly due to early ignition before top dead center and to permit combustion to take place for an extended period of time.

3. A method according to Claim 1 for controlling the movement of a piston in an internal combustion engine of the diesel type, characterized in that the injection of fuel and the consequent initiation of combustion is performed while the piston is substantially halted at top dead center to thereby avoid the back pressures formerly due to the ignition of diesel fuel injected before top dead center.

4. A method for controlling the movement of a piston according to any one of Claims 1 to 3 wherein the reciprocating engine has an exhaust valve and an inlet

valve, characterized in that the operations of closing the exhaust valve and/or opening the inlet valve are performed, at least in part, while the piston is substantially halted at top dead center.

5. A device for implementing the method according to any one of Claims 1 to 4 comprising a reciprocating engine having a piston working in a cylinder and a combustion and/or expansion chamber that is separate from but in fluid connection with the cylinder, characterized in that the displacement of the piston (1) is controlled by a pressure lever consisting of two arms (3, 4) articulated together one of which arms has a stationary end (6) and the other (3) of which arms has a free end connected to the piston pin of the piston (1) which moves along the axis of the cylinder when force is exerted on the pin (5) common to the two arms (3, 4), said force being transmitted by a control connecting rod (7) which connects the pin (5) common to the two arms (3, 4) of the pressure lever to the wrist pin (8) of a crankshaft (9) positioned laterally with respect to the axis of displacement of the piston (1), said control connecting rod (7) driving the rotation of the crankshaft when the forces are applied to the piston (1) during the power stroke, and, characterized in that when the arms (3, 4) of the pressure lever are aligned on an axis of alignment (X', X), the position of the stationary end (6) determines an first angle (A) and the lateral positioning of the crankshaft (9) determines a second angle (B) between the control connecting rod (7) and the axis of alignment (X', X) of the two arms (3, 4) of the pressure lever, it being possible for the angles thus determined to be positive, negative or not simultaneously zero.

6. A device according to Claim 5, characterized in that the variation of the values of the angles formed between the axis of alignment (X', X) of the two arms (3, 4) of the pressure lever and the axis of displacement of the piston (A), and between the axis of alignment (X', X) and the control connecting rod (7) (B), of the lengths of the control connecting rod (7) and of the arms (3, 4) of the pressure lever, dictate the overall dynamics of the device and determines the angle of rotation of the crankshaft during which the piston is substantially halted at top dead center.

7. A device according to Claims 6 or 7, characterized in that, for balancing purposes, the lower arm (4) of the pressure lever is extended beyond its stationary end or pivot (6) by a mirror-image piston lever consisting of two arms (4A, 3A) articulated to a common pin (5A) to which is attached, at the free end (1B), a mass (15) moving along an axis parallel to the axis of displacement of the piston (1) and in such a way that, with respect to the stationary end or pivot (6), the moment of inertia of the arms connected to the stationary end (4,4A) of the articulation pins (5, 5A), of the arms connected to the piston and to the mass (3,3A) and the moment of inertia of the piston (1) and that of the balancing mass (15) are identical to each other.

8. A device according to Claim 7, characterized in that the balancing mass is an opposed piston (1C), the weight, moment of inertia and operation of which are identical to those of the main piston (1).

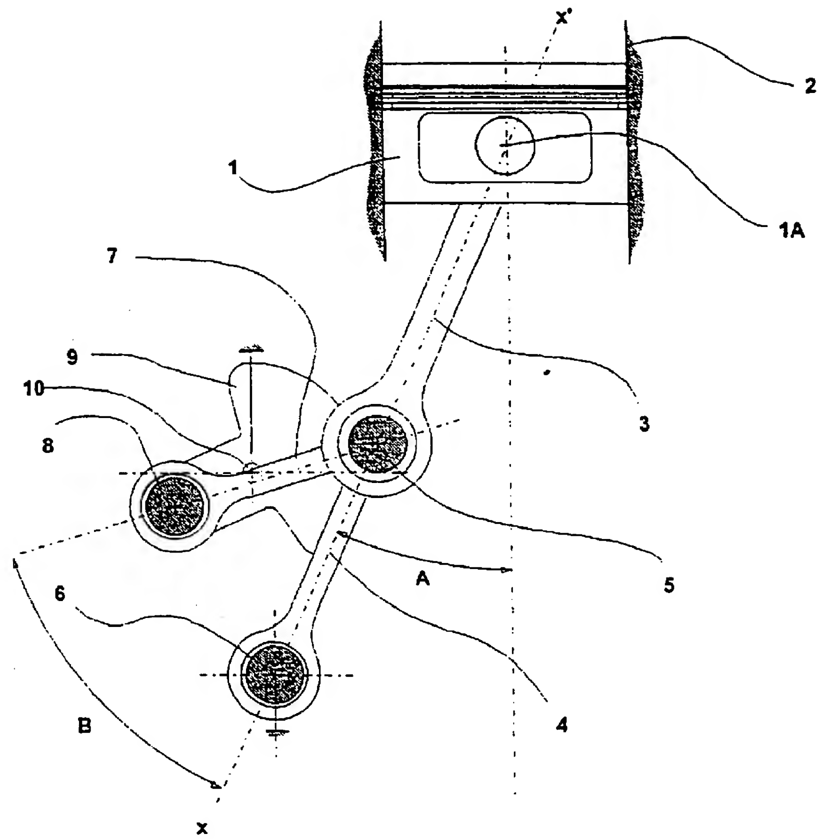
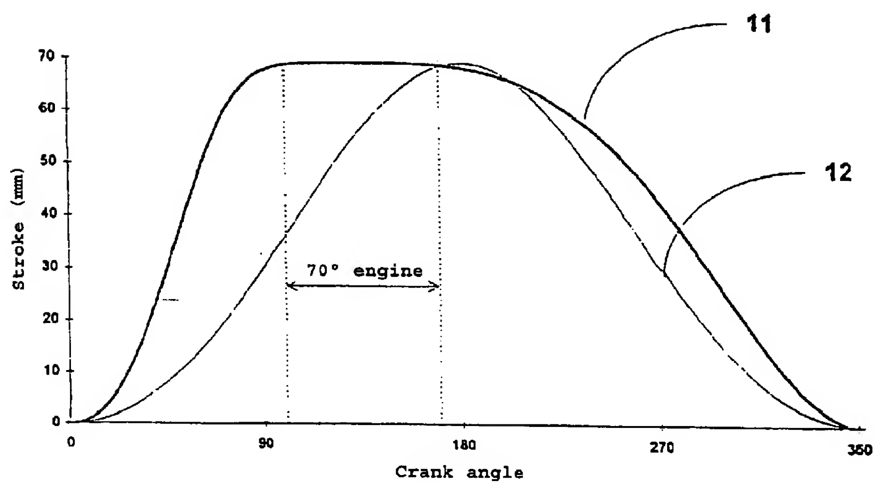


Fig. 1



11
12
70
60
50
40
30
20
10
0
Stroke (mm)
70° engine
0
90
180
270
360
Crank angle

Fig.2

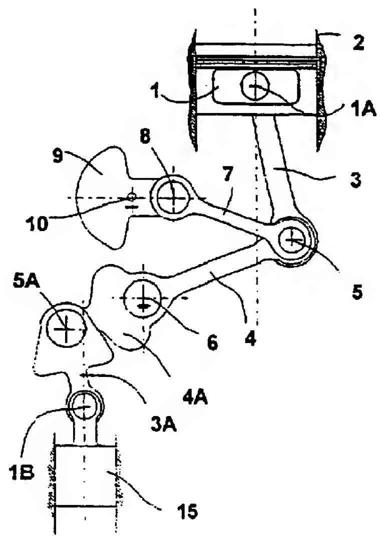


Fig. 3

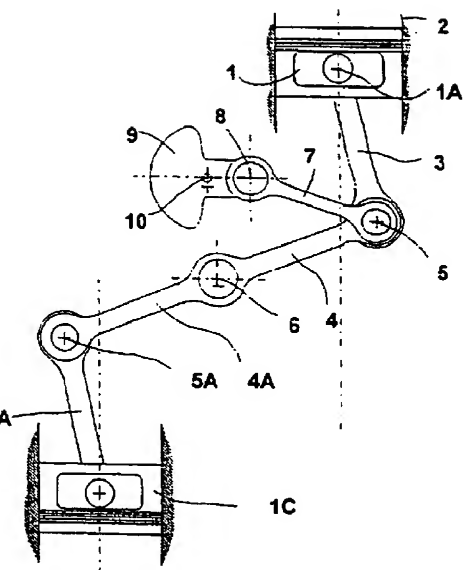


Fig. 4